NAME ________________________________
Section:_______
Physics 315
Problem Set 1
100 points
Due: *Beginning of class*, Lesson 6

To receive full credit you must show all work, communicate efficiently using proper grammar, and for every short answer (e.g. yes, no, maybe, it depends, I don't know) include an explanation why.

AUTHORIZED RESOURCES: *any published or unpublished sources and any individuals*.

Document appropriately!

Assume the speed of sound is always 343 m/s or 1087 ft/sec.
A knot is a nautical mile per hour and a nautical mile is 6076 feet.

Note: Some of the attached figures are easier to interpret in their color versions, which you can find on the course web site under "Handouts".

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1. For this problem, use the attached V-n diagrams for the mighty Rhino and the F-16.

a) Identify the airspeed where the tightest, fastest turn would occur for a lightweight F-4 at sea level. Briefly explain why you chose this point, and describe what would happen to the maximum turn rate and minimum possible radius if you were to move slightly above (faster) and slightly below (slower) the point you chose. In explaining these rate/radius variations, use English words, mathematical symbols and equations as appropriate.
b) What is the F-4's best rate and radius of turn? If you can find a chart for this, use it! If not, suck it up and do the math. Compare these values to those for a lightweight F-16 at sea level using the appropriate turn performance chart. Just how much better is the Viper?
c) The charts show allowed V-n combinations for "symmetrical" and "unsymmetrical" maneuvers. Symmetrical maneuvers are those where the stick is pulled straight back, causing no roll. Unsymmetrical maneuvers not only increase the load factor, but cause the aircraft to roll as well (thus, they're typically called "rolling G's" by pilots). Explain why the unsymmetrical maneuver envelope is smaller that the symmetrical envelope. *(Hint: Accelerometers measure the load factor only at the aircraft fuselage.)*

2. The Eagle also enjoys a considerable advantage in performance over the Rhino. In fact, an average combat weight F-15 can sustain about an 8 G turn, while the F-4 can pull about the same amount of Gs for only a short time. Using the "energy egg" concept, briefly explain how a well-flown F-4 could win a turning fight against an average Eagle pilot who is afraid to use the vertical (and what Eagle pilot ISN'T just average???). The use of simple free-body diagrams for several points along the flight paths of both jets would probably be helpful to both your understanding of and your score on this problem. As further motivation, the first computer exercise we will do in this class will attempt to model this very situation.

3. For this problem, use the attached 1G H-M diagrams for the F-4 and F-15. Include the performance charts for the F-16 for part b, and use the F-4 vs. MiG 21 at 1G and 5G diagrams for part c.

a) What does the curve labeled zero (0) represent on the 1G H-M diagrams? Of the F-4 and the F-15, which aircraft can fly faster for an extended period? Which aircraft has a higher service ceiling? Can the F-4 ever operate subsonic above 55,000 ft? If not, why; if so, how?
b) What is the maximum instantaneous climb rate an F-4 can attain (**in ft/min**, the number you'd read off of your VVI, the vertical velocity indicator) at 0.8 Mach (while maintaining a constant airspeed)? What about for the F-15? How about the F-16? What is the maximum level acceleration (kts/sec) that each aircraft could attain at 30,000 ft?
c) What does the line labeled zero (0) on the F-4 vs. MiG 21 at 1G diagram represent? Approximately how much specific excess power does the MiG 21 have at Mach 1 and 15,000 ft? Which jet performs better at 5 Gs if they are fighting at Mach 0.75 and 10,000 ft? How much faster can the better-performing jet climb (ft/min) under these conditions?

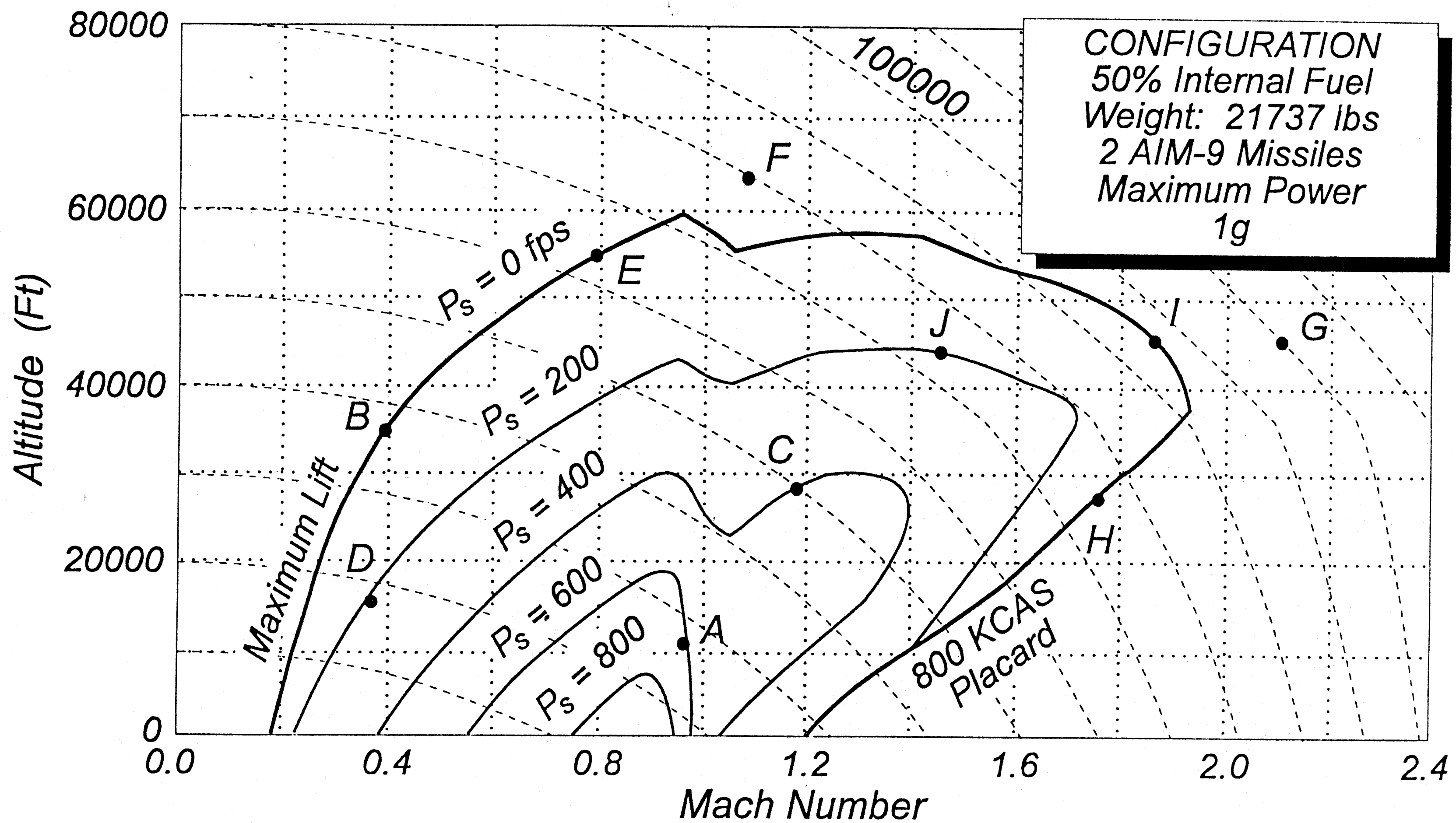
4. From problem three, it is apparent that the specific excess power available to any fighter is highly dependent upon how many Gs the jet is pulling. Explain what specific excess power actually represents, and using the appropriate relationships for lift and drag, explain why the values on a H-M diagram should become more negative as aircraft G increases.

5. G-loading is not the only factor that determines specific excess power. Use the appropriate F-16 turn performance charts for the following questions.
a) Can a "clean" Viper (configured for air-to-air with only missiles and gun, 0 drag index and lightweight) sustain a level 9G turn at sea level? How about without the use of the afterburner (i.e. in military or "mil" power)? How about at 30,000 ft with the AB?
b) Compare the performance at sea level of a clean Viper to one laden with bombs, an ECM pod, and external tanks (drag index of 200 and heavyweight). It gets worse. When loaded up, the jet should be flown with the Cat III limiter on (this limits AOA at lower airspeeds to keep the aircraft from departing) and kept under 5.5 Gs (to keep the MK-84s from becoming "hung"). With these limits, what are the best rate and radius?
c) With the answer to part b in mind, what are you going to do when faced with a Flanker that wants to mix it up with you while you're ingressing to the target?

6. From the point of view of a fighter pilot teaching a physics class, what is the most damning quote in the appendix of Shaw? How can said fighter pilot escape the damaging conclusions of this quote?

F-15C

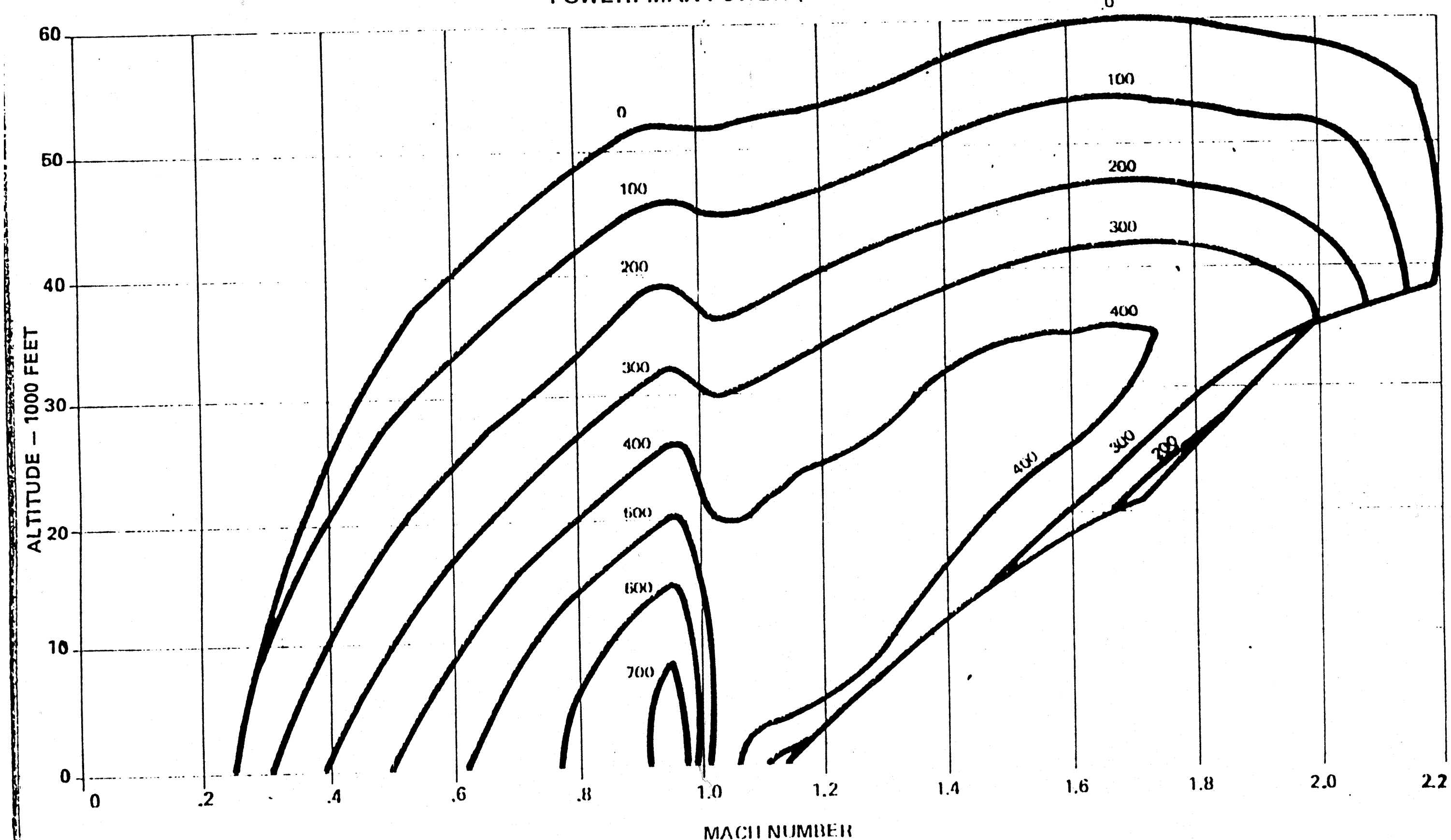
SPECIFIC EXCESS POWER



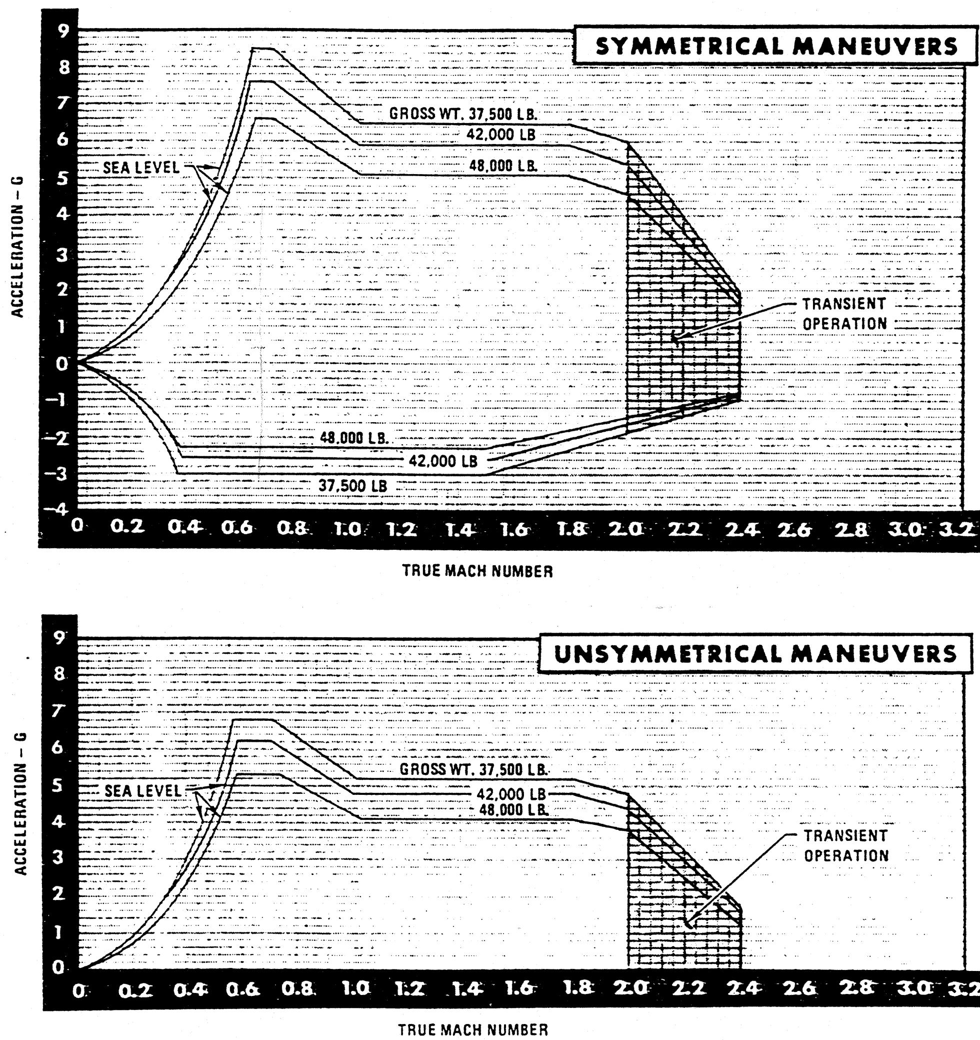
F-4 at 1G

SPECIFIC EXCESS POWER

CLEAN CONFIGURATION – WEIGHT: 35,840 lbf (INT GUN & AMMO) –
POWER: MAX POWER (J79-17 ENGINES)



FLIGHT STRENGTH DIAGRAM



4E–1–(34) B

Figure 5-9

Turn Performance — Sea Level

DATA BASIS FLIGHT TEST **ENGINE F110-GE-100/BIG INLET**

CONFIGURATION:
- DRAG INDEX = 0
- GW = 20,000 POUNDS

CONDITIONS:
- STANDARD DAY
- MIL

NOTE: REFER TO SECTION V FOR AIRSPEED LIMITATIONS.

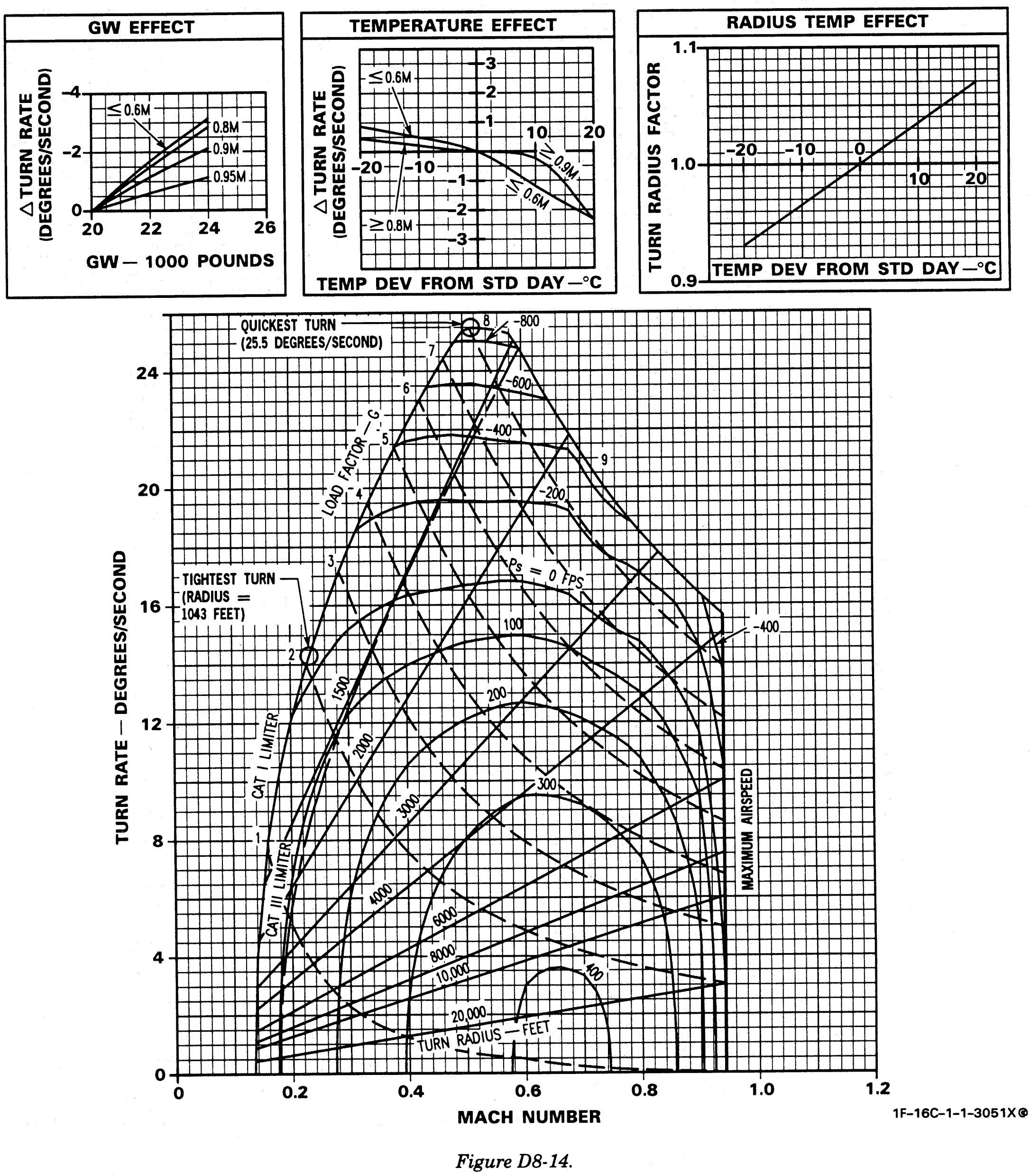


Figure D8-14.

Turn Performance — Sea Level

DATA BASIS FLIGHT TEST **ENGINE F110-GE-100/BIG INLET**

CONFIGURATION:
- DRAG INDEX = 0
- GW = 20,000 POUNDS

CONDITIONS:
- STANDARD DAY
- MAX AB

NOTE: REFER TO SECTION V FOR AIRSPEED LIMITATIONS.

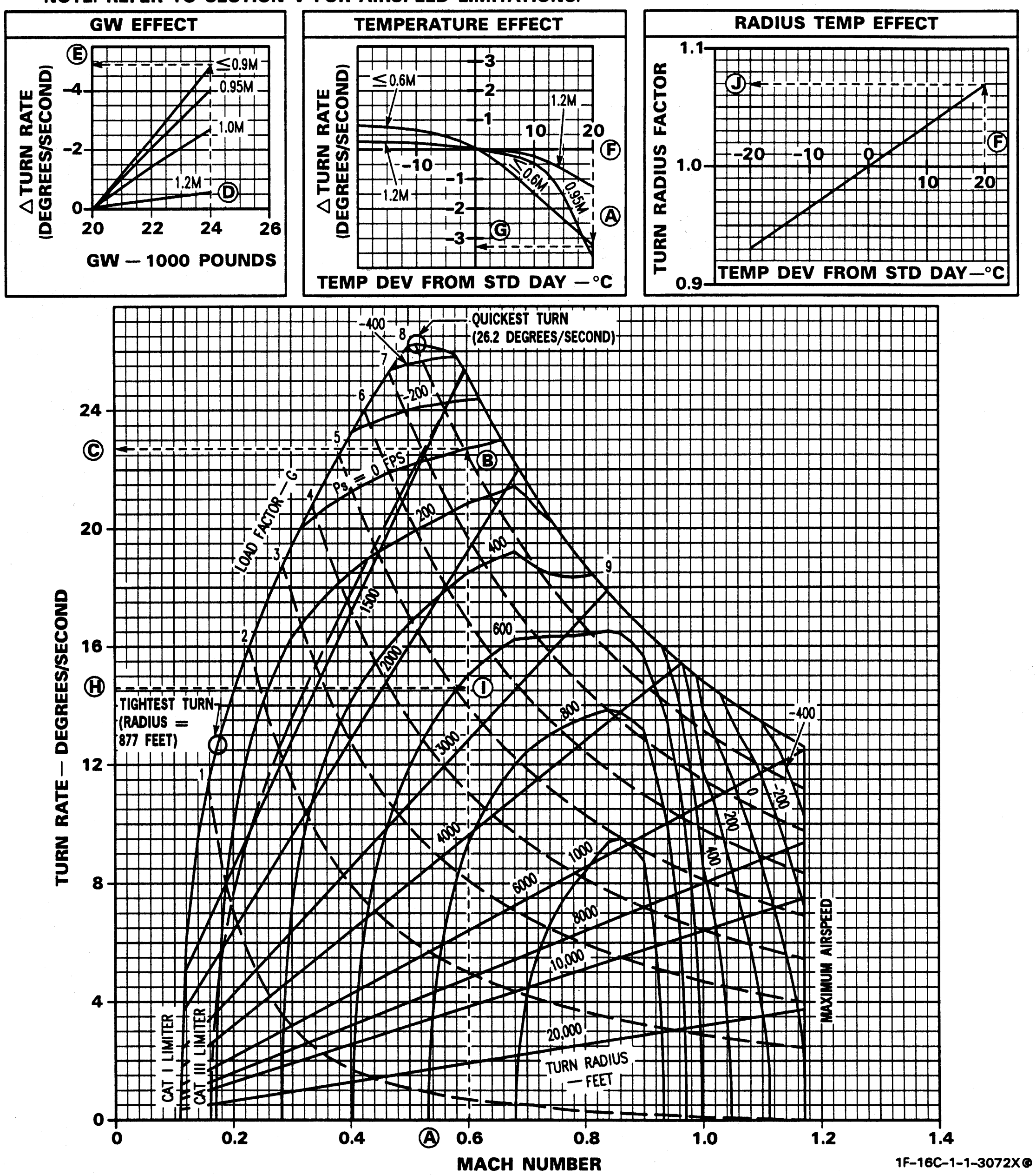


Figure D8-35.

Turn Performance — 30,000 Feet

DATA BASIS FLIGHT TEST | **ENGINE F110–GE–100/BIG INLET**

CONFIGURATION:
- DRAG INDEX = 0
- GW = 20,000 POUNDS

CONDITIONS:
- STANDARD DAY
- MAX AB

NOTE: REFER TO SECTION V FOR AIRSPEED LIMITATIONS.

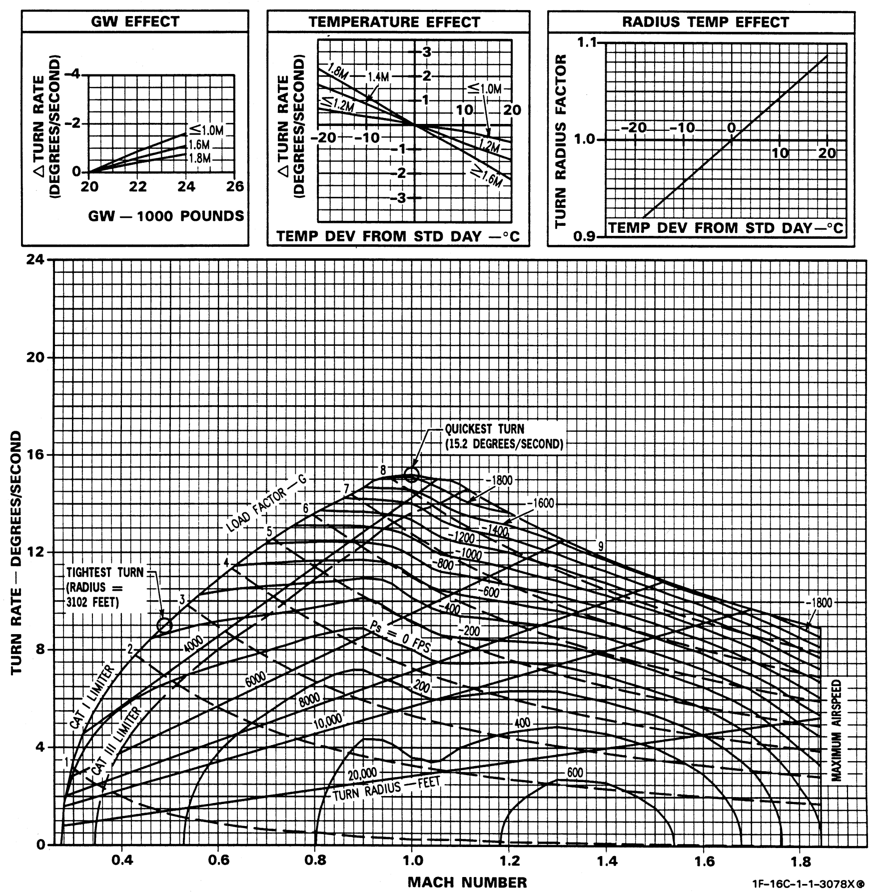


Figure D8-41.

Turn Performance — Sea Level

DATA BASIS FLIGHT TEST | **ENGINE F110-GE-100/BIG INLET**

CONFIGURATION:
- DRAG INDEX = 200
- GW = 29,000 POUNDS

CONDITIONS:
- STANDARD DAY
- MAX AB

NOTE: REFER TO SECTION V FOR AIRSPEED LIMITATIONS.

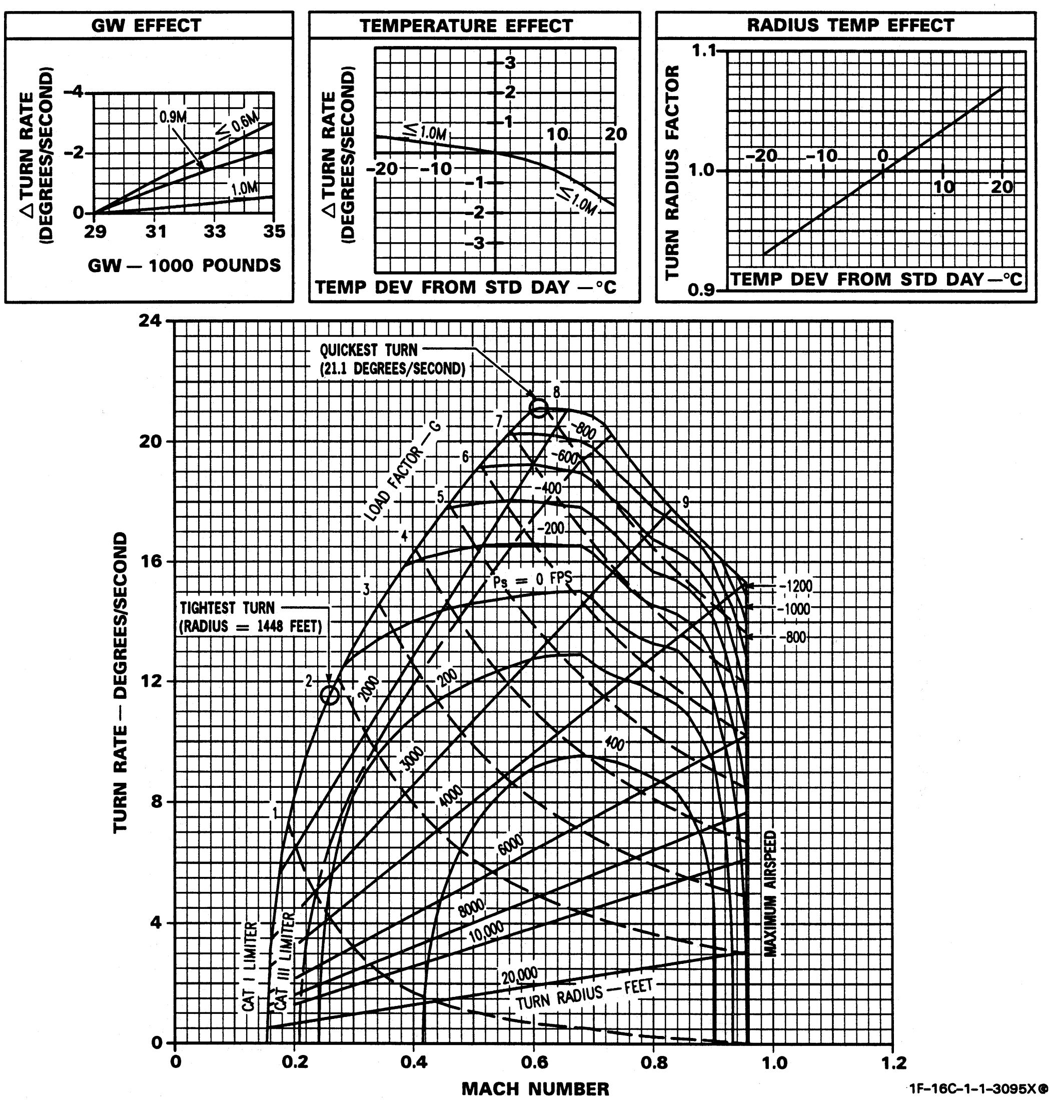
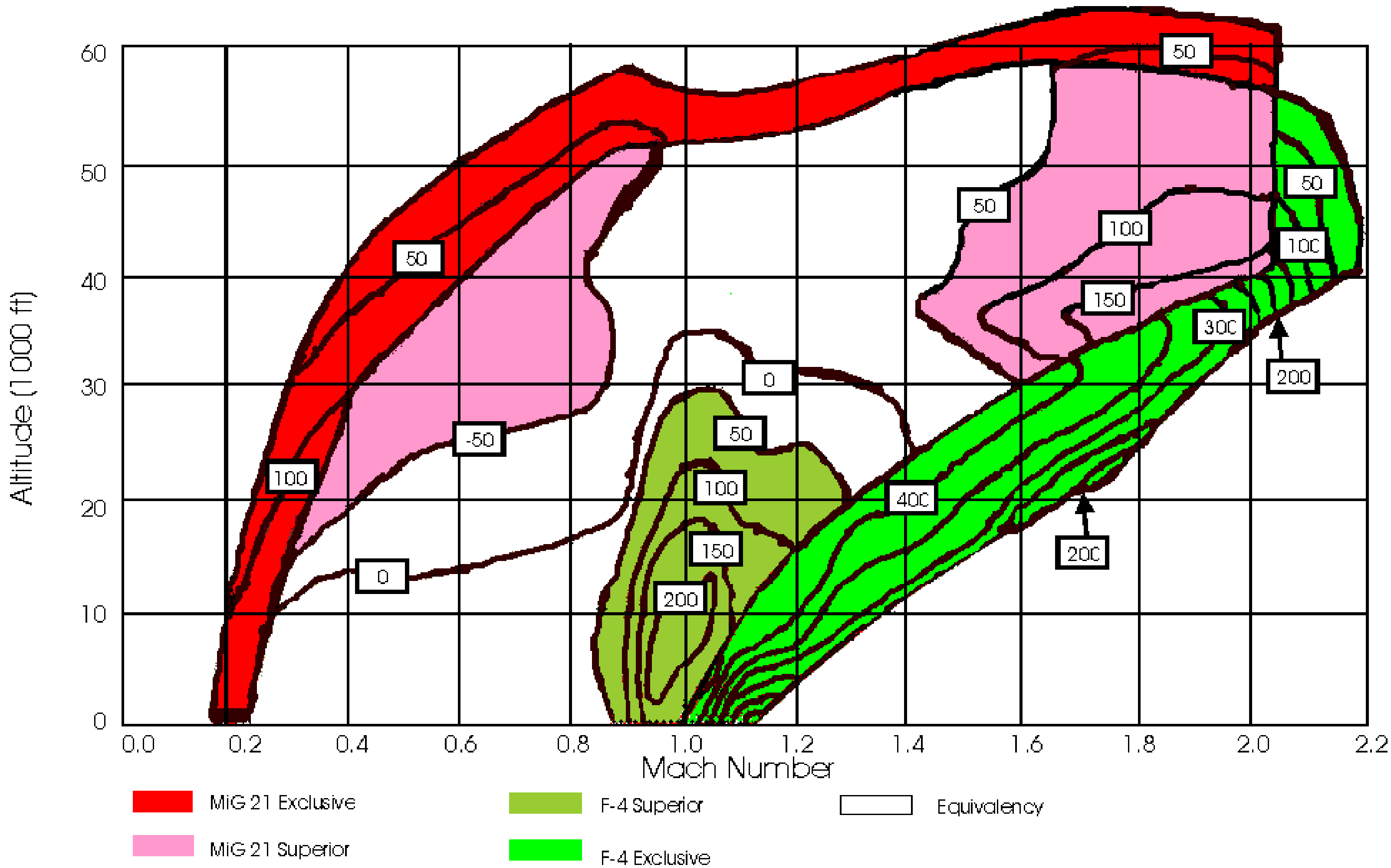


Figure D8-58.

F-4 vs. MiG 21 at 1G

Differential Specific Excess Power Contours

Clean Configuration -- 50% Fuel -- Full Ammo -- Max A/B



F-4 vs. MiG 21 at 5Gs

Differential Specific Excess Power Contours

Clean Configuration -- 50% Fuel -- Full Ammo -- Max A/B